Chapter 48

SPECIALIST EQUIPMENT FOR PAIN MANAGEMENT

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INTRODUCTION

Historically times of conflict are associated with acceleration in the evolution of medical therapies. As the enemy develops new weaponry and technology designed to inflict injury and pain, the medical community furthers advancement in surgical and resuscitative techniques, resulting in increased injury survival.[1] However, this increased survival presents further challenges to the medical community. Injury patterns have shifted so that the ratio of extremity to head and torso injuries is increasing, and soldiers are surviving complex wounds that previously would have been fatal.[2]

To meet these demands, the plethora of advanced analgesic techniques common to civilian practice must be incorporated into military medical practice and adapted to the demands of the austere military healthcare environment. The nature of combat medical treatment facilities, where patients are rapidly stabilized and moved through a casualty evacuation chain, requires advanced pain management systems that are noncomplex and efficacious, require minimal user intervention, and ideally are intuitively familiar to systems used in civilian practice. Not all systems developed for use in civilian practice, however, are suited to the military environment.

Recent advances in battlefield analgesia have been focused on the ability of regional anesthesia to provide selective sensory analgesia while limiting, if not eliminating, the cognitive and respiratory depressant effects associated with parenteral opioids. Single injection nerve blocks, continuous peripheral nerve block (CPNB) catheters, and neuraxial anesthesia have become a major component of pain management in combat-related injuries. Peripheral nerve blocks of extremities have the ability to isolate an affected limb, while transversus abdominis plane blocks, well established as effective analgesia in postsurgical patients, can be used to manage traumatic abdominal pain when neuraxial anesthesia is contraindicated.[3–5]

Specialist pain management equipment used in the deployed environment can be broadly divided into that which facilitates and delivers the targeted placement of local anesthetic solutions and that which delivers systemic analgesia. By necessity administering analgesic medication in these modalities requires specialist devices and equipment.

NERVE LOCALIZATION

Electrical Nerve Stimulator

The use of electrical stimulation has been shown to be an inexpensive, uncomplicated, and portable means of nerve localization for regional anesthesia.[6] These advantages make stimulation a particularly attractive option for use in the deployed environment. During the placement of a peripheral nerve block, stimulation needles may be used both to detect proximity to nerves and to inject the local anesthetic solution. During the procedure, the nerve stimulator electrical cable must be connected to both the stimulation needle wire and the skin electrode to assure that, once the needle tip has contacted skin, a complete circuit exists. Initial currents should be set at 1 to 2 mA with a pulse width of 0.1 millisecond and frequency of 60 to 120 Hz. Current amplitude should be variable and capable of gradual reduction to 0.1 to 0.2 mA. A stimulating current threshold of 0.2 to 0.5 mA indicates adequate proximity to the nerve, and brisk twitches at currents of less than 0.2 mA may indicate an intraneural placement of the needle. Nerve stimulator design should include audible function and failure signals.

Medical Ultrasound

Application of medical ultrasound has revolutionized many areas of battlefield trauma management. Using data gleaned from the 2006 conflict between Hezbollah and Israel, Beck-Razi et al found the positive and negative predicted value of focused assessment with sonography for trauma (FAST) to be 88.2% and 94.1%, respectively.[7] The authors hypothesized that the use of FAST at point of injury likely prevented several unnecessary emergency laparotomies and thus minimized surgical pain.

Ultrasound-guided regional anesthesia (using medical ultrasound in the targeted placement of local anesthetics) has dramatically increased in popularity over the last 5 years. Although outcome data from head-to-head clinical trials has yet to provide sufficient evidence for making ultrasound use the standard of care, its theoretical advantages over stimulation are hard to ignore.[8,9] These potential advantages include direct visualization of nerve structures, reduced incidence of accidental vascular puncture, and increased patient comfort.[10]

Identification of peripheral neural structures requires ultrasound optimized for this purpose. High-frequency probes are required (8–15 MHz) combined with machines sufficiently portable to for performing nerve blocks at the bedside. Elements of an optimum ultrasound machine for combat regional anesthesia include high image quality;

compact, lightweight, and durable design; simple and intuitive controls; and easy image storage and retrieval.[11] Modern, affordable, and portable ultrasound technology for needle placement is making its way closer to the point of injury on the battlefield, and in the near future combat healthcare providers may be equipped with these next-generation lightweight devices.

NEEDLE DESIGN

Peripheral nerve block needles, as opposed to traditional hypodermic needles, are designed with a bevel angled at 20° to 30° (Figure 48-1). This blunted angle facilitates the detection of tissue planes and fascial layers as the needle tip is advanced toward its intended target. The blunted design also results in a non-cutting needle that may reduce the risk of neural tissue injury during procedures that invariably bring the needle tip within close proximity to neural structures.[12] A separate design for catheter insertion (epidural and peripheral) is the Tuohy needle, with a non-cutting tip, angled distal aperture, and graduated markings for more precise measurements. The needles may also be insulated throughout their length, excepting the tip, to facilitate nerve localization by electrical stimulation.

CATHETER TECHNIQUES

The CPNB delivers a continuous infusion of local anesthetic to a targeted site, enabling the duration of block provided by local anesthetics to be extended beyond the typical 8 to 20 hours achieved by a single injection technique. In the deployed setting a CPNB may be used to provide prolonged postoperative analgesia, including the time necessary to transfer between roles of care. Additionally, it may be used for the provision of regional anesthesia when patients require repeated surgical procedures, obviating the need for multiple general anesthetics.

Irrespective of the austere nature of the deployed environment, catheter insertion techniques should be undertaken in aseptic conditions with appropriate skin decontamination and draping with a sterile field. Ultrasound probes should be contained within a sterile sleeve when used.

Catheter kits are available for both central neuraxial and regional nerve block techniques, an example being the Braun Contiplex Touhy system (B Braun, Melsungen, Germany). Epidural sets contain a needle of Tuohy design, catheter, connector, and filter assembly, and needles for regional techniques may in addition have an insulated sheath, integrated wire for electrical stimulation, and diaphragm allowing for catheter insertion.

MEDICATION DELIVERY SYSTEMS AND PATIENT-CONTROLLED ANALGESIA

Continuous delivery of analgesic medication requires the use of a pressurized delivery system. Intravenous delivery systems are used primarily to administer opioids and ketamine, while perineural delivery systems are used for local anesthetics with or without additive medications.

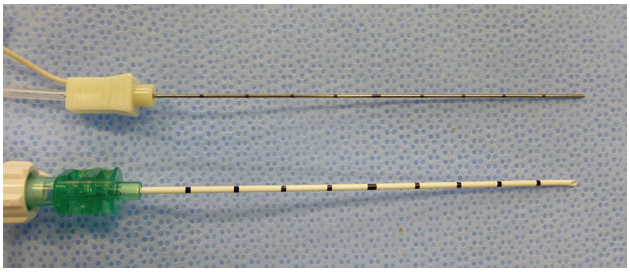

Figure 48-1. Examples of beveled nerve block needles. Above: a stimulating, non-echogenic single-shot peripheral nerve block needle; below: a non-stimulating, echogenic needle for the placement of a continuous nerve block catheter. Both products copyright B Braun Melsungen AG (used with permission).

Patient-controlled analgesia (PCA) involves the use of an infusion pump that delivers a preprogrammed dose of opioid when the patient pushes a demand button. The concept of the PCA has been in existence since the 1960s, but detailed pharmacologic work on the system began in earnest in the 1970s.[13] This pharmacokinetic and pharmacodynamic research resulted in two main concepts achieved by PCA administration of opioids: (1) individualized dosages titrated to pain relief response to achieve the MEAC (minimum effective analgesic concentration) and establish analgesia, and (2) constant plasma opioid concentrations, avoiding peaks and troughs (Figure 48-2).[14]

All modes of PCA include the following basic variables: initial loading dose, demand dose, and lockout interval. For PCA to be successful, the demand dose should produce appreciable analgesia with a single demand.[15] The lockout interval is designed to prevent

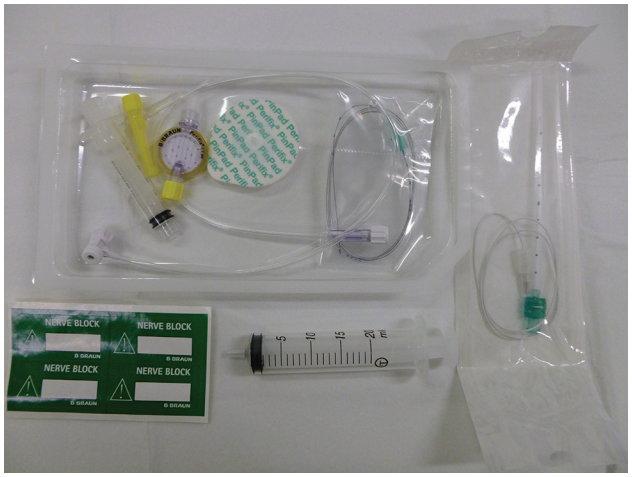

Figure 48-2. Sterile continuous nerve block set. Copyright B Braun Melsungen AG (used with permission).

overdose. Ideally, it should be long enough for the patient to experience the maximal effect of one dose before another is permitted, thus preventing "stacking" of doses.[16] All of the commonly used opioids have been successfully employed for PCA dosing. Based on the patient's individual comorbidities (eg, potentially avoiding morphine in renal failure patients) and pharmacokinetic profile of the medication, morphine, hydromorphone, and fentanyl are all reasonable choices to initiate PCA.

In addition to the targeted approach to the therapeutic window, there is additional safety in utilizing intravenous opioid PCA through a physiological negative feedback loop: the patient is likely to become too sedated to physically push the button to receive more opioid before reaching a critical point of severe respiratory depression.[17] Patient-controlled intravenous ketamine administration has been used as an alternative to opioids in the deployed setting, where the risks associated with potential respiratory depression in an austere environment are considered significant. Ketamine has a long established history of providing profound analgesia while maintaining spontaneous respiration. The most feared side effect of ketamine, especially in the combat-wounded population, is a negative hallucinogenic psychotropic effect. At low doses (10–20 mg/h basal infusion or 5–10-mg bolus with a 10-min lockout) however, this effect is typically not a problem.

Both intravenous and perineural infusion systems have the option to administer medication continuously, as a bolus, or a combination of the two. These devices can be broadly divided into those that generate the requisite infusion pressure by an electrically powered mechanism and those that power the infusion by elastomeric forces.

Electrically powered infusion devices may be driven by roller pumps or mechanical screws. Elastomeric pumps generate a pressure for administration through an elastic layer within the pump. When filled, the distension of the elastomeric layer delivers a driving pressure, and the rate of infusion is controlled by a temperature-sensitive flow restrictor downstream (solution viscosity varies with temperature, resulting in faster or slower flow rates).[18] Each system comes with unique advantages and disadvantages when used in the deployed environment (Figure 48-3).

Elastomeric infusion devices have a number of advantages when compared to electromedical equipment. They are single-use, disposable items with no requirement for servicing.[19] No external or battery power source is required, and when the patient transits through different stages of the medical evacuation chain, there is no need to change the devices, which may be assigned to a fixed location. There are also several disadvantages to elastomeric devices in the deployed environment. They typically are not reprogrammable and therefore are somewhat limited in mission capability. In addition, the pumps are sensitive to pressure differences in aircraft, which is not the case for electronic pumps.[20] Flexibility in bolus functions is also limited.[21]

Electronic devices, however, typically have incorporated pressure sensors, detecting when flow rates fall or stop, as well as a memory function, allowing information such as volumes administered and number of user interactions to be obtained from the pump.[22] This latter capability is particularly useful for acute pain issues, such as determining patient analgesic requirements. Each type of device has potential benefits, and choice should reflect both the clinical and military environment of the deployed operation while meeting regulatory body guidance and maintaining patient safety.

Medication delivery systems for local anesthetics and opioids remain an area of ongoing research and clinical development. Transdermal delivery systems utilizing the process of iontophoresis may provide a new route for opioid administration in the deployed environment, and liposomal encapsulation of local anesthetics may obviate the need for catheter infusions by significantly increasing an agent's duration of action. Potential benefits of new and novel routes of drug delivery may include eliminating the need for intravenous access, decreasing medication errors, and eliminating the risk of PCA programming errors.

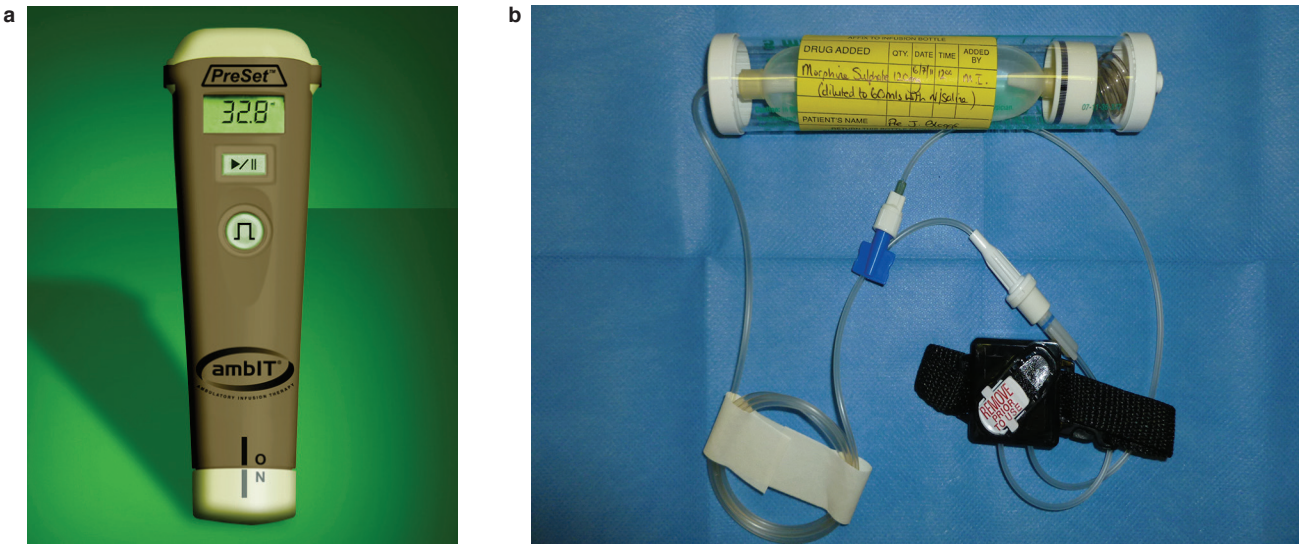

Figure 48-3. (a). ambIT electronic infusion pump (Summit Medical Products, Inc, Salt Lake City, UT); used with permission. **(b)** On-Q elastaomeric infusion device. Copyright B Braun Melsungen AG (used with permission).

SUMMARY

In most major catastrophic events, be it war or natural disaster, human innovation and medical necessity combine to promote novel, adaptable medical care to maximize casualty survival. Advanced analgesic techniques have been adapted and assimilated, becoming a fundamental part of patient management in the battlefield. By necessity there is an associated requirement for specialist equipment, both robust and suitable for the austere military environment. As we continue to improve the means by which we provide care for wounded soldiers, we will continue to increase their survival and improve their rehabilitation.

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